

Argonne Nuclear Data Program

□ Nuclear Data **Compilations & Evaluations**

- ✓ nuclear structure compilations and evaluations - **ENSDF & XUNDL**
- ✓ evaluation of atomic masses and nuclear properties - **AME & NuBase**
- ✓ decay data evaluations in support of IAEA-led projects & other horizontal evaluations (nuclear isomers, B(E3), ND for Monitoring Applications)

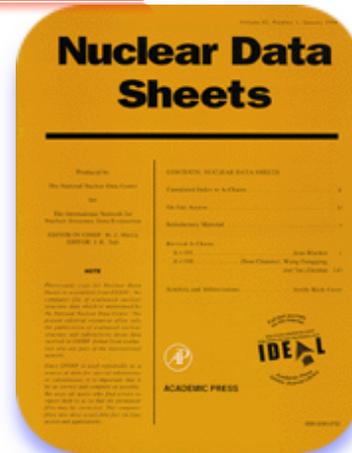
□ Complementary ND **Research** Activities

- ✓ intersections between basic and applied nuclear physics & astrophysics - via collaborative agreements with a little or no cost to USNDP
- ✓ contributions to DOE/NP FOA's - 2 funded at the FY17 call

Evaluations & Compilations - FY19

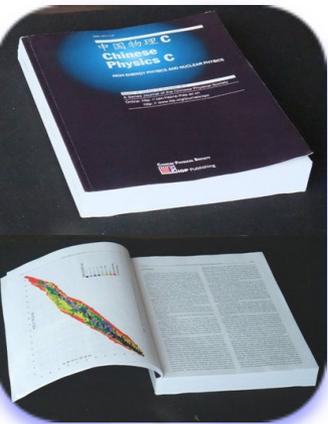
ENSDF

- **A=177** was completed and published in NDS
- **A=205** was completed and submitted to NNDC
- started working on **A=203**
- reviewed of **A=100** (completed) and **190** (ongoing)



XUNDL

- compiled what we were asked to do - not much - a few papers from the IAEA-ICTP workshop ...
- in the past compiled RIKEN-produced papers with Yuichi Ichikawa (RIKEN) - no requests for compilations during FY19 - discontinued the collaboration



AME & NUBASE

- continued compilation & evaluation activities

IAEA-NDS collaborations

- IAEA-ICTP workshop; NSDD; TM on Antineutrino spectra; TM on ENSDF codes (benchmarking & code development); TM on ND for monitoring applications

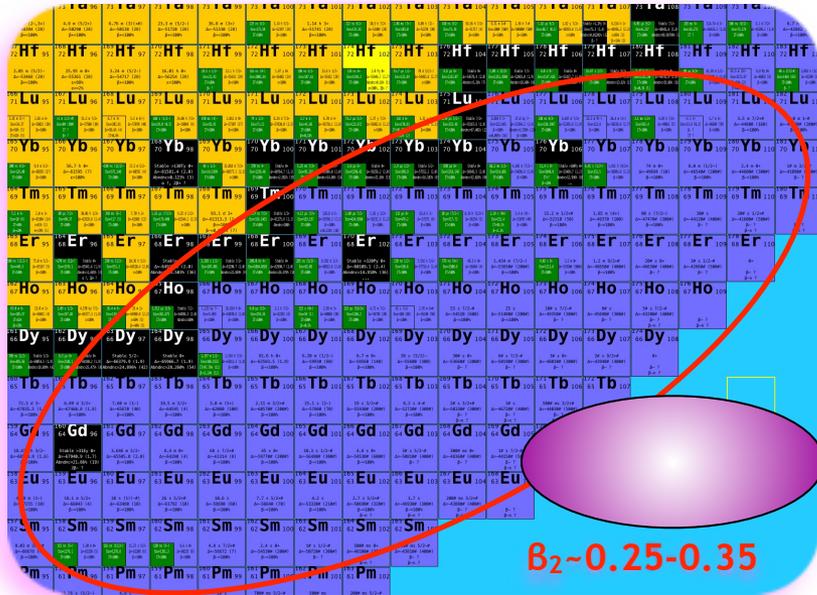
Nuclear Data Research Activities

intersections between the basic and applied NP & astrophysics

- complements and benefits the evaluation activities
- sought after collaborator with little or no cost to USNDP

- ❑ at ANL (ATLAS & CARIBU) - nuclei far from stability, spectroscopy of heavy and super-heavy nuclei, K-isomers, beta-decay spectroscopy & mass measurements in the FP region; *decay spectroscopy* of actinide nuclei and nuclei of importance to applications of medical isotopes and metrology
 - ✓ **present:** CARIBU - properties of neutron-rich nuclei (nuclear structure & masses, astrophysics & applications); FOA's funded projects
 - ✓ **future:** nuCARIBU & N=126 factory
- ❑ at MSU (Coulex & decay spectroscopy) & RIKEN (decay spectroscopy) - properties of neutron-rich nuclei far from the line of stability

deformed light rare-earth region



PHYSICAL REVIEW LETTERS **120**, 182502 (2018)

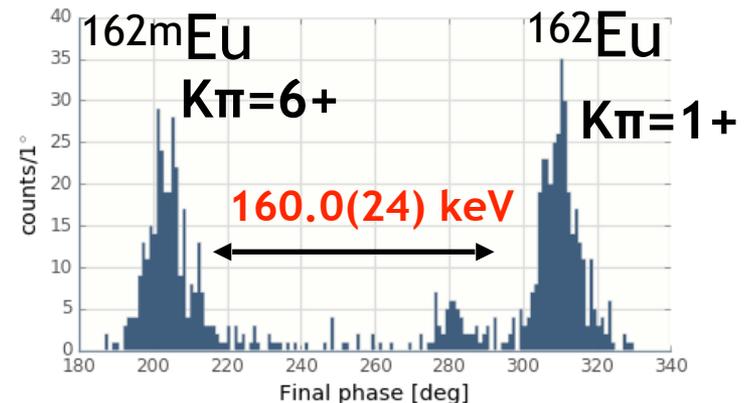
Masses and β -Decay Spectroscopy of Neutron-Rich Odd-Odd $^{160,162}\text{Eu}$ Nuclei: Evidence for a Subshell Gap with Large Deformation at $N=98$

D. J. Hartley,¹ F. G. Kondev,² R. Orford,^{2,3} J. A. Clark,^{2,4} G. Savard,^{2,5} A. D. Ayangeakaa,^{2,*} S. Bottoni,^{2,†} F. Buchinger,³ M. T. Burkey,^{2,5} M. P. Carpenter,² P. Copp,^{2,6} D. A. Gorelov,^{2,4} K. Hicks,¹ C. R. Hoffman,² C. Hu,⁷ R. V. F. Janssens,^{2,‡} J. W. Klimes,² T. Lauritsen,² J. Sethi,^{2,8} D. Seweryniak,² K. S. Sharma,⁹ H. Zhang,⁷ S. Zhu,² and Y. Zhu⁷

- combination of mass spectrometry (PI-ICR) & decay spectroscopy
- beta-decaying isomers in ^{160}Eu & ^{162}Eu - changes in the single-particle structures
- discrepancies with RIKEN (decay) & Jyvaskyla (masses - confirmed our results)

$\pi 5/2[413]$ $\nu 7/2[633]$

$^{160}_{65}\text{Tb}_{95}$ 72.3 d 3- $\Delta = -67835.5$ (1.8) $\beta = 100\%$	$^{161}_{65}\text{Tb}_{96}$ 6.89 d 3/2+ $\Delta = -67460.8$ (1.8) $\beta = 100\%$	$^{162}_{65}\text{Tb}_{97}$ 7.60 m (1-) $\Delta = -65670$ (40) $\beta = 100\%$	$^{163}_{65}\text{Tb}_{98}$ 19.5 m 3/2+ $\Delta = -64595$ (4) $\beta = 100\%$	$^{164}_{65}\text{Tb}_{99}$ 3.0 m (5+) $\Delta = -62080$ (100) $\beta = 100\%$	$^{165}_{65}\text{Tb}_{100}$ 2.11 m 3/2+# $\Delta = -60570\#$ (200#) $\beta = 100\%$	$^{166}_{65}\text{Tb}_{101}$ 25.1 s (2-) $\Delta = -57880$ (70) $\beta = 100\%$
$^{159}_{64}\text{Gd}_{95}$ 18.479 h 3/2- $\Delta = -68560.8$ (1.6) $\beta = 100\%$	$^{160}_{64}\text{Gd}_{96}$ Stable >31Ey 0+ $\Delta = -67940.9$ (1.7) Abndnc=21.86% 28- ?	$^{161}_{64}\text{Gd}_{97}$ 3.646 m 5/2- $\Delta = -65505.0$ (2.0) $\beta = 100\%$	$^{162}_{64}\text{Gd}_{98}$ 8.4 s (4) $\Delta = -64...$ (4)	$^{163}_{64}\text{Gd}_{99}$ 68 s 7/2+# $\Delta = -61314$ (8) $\beta = 100\%$	$^{164}_{64}\text{Gd}_{100}$ 45 s 0+ $\Delta = -59770\#$ (200#) $\beta = 100\%$	$^{165}_{64}\text{Gd}_{101}$ 10.3 s 1/2-# $\Delta = -56490\#$ (300#) $\beta = 100\%$
$^{158}_{63}\text{Eu}_{95}$ 45.9 m (1-) $\Delta = -67255$ (10) $\beta = 100\%$	$^{159}_{63}\text{Eu}_{96}$ 18.1 m 5/2+ $\Delta = -66043$ (4) $\beta = 100\%$	$^{160}_{63}\text{Eu}_{97}$ 38 s (1-)# $\Delta = -63480$ (10) $\beta = 100\%$	$^{161}_{63}\text{Eu}_{98}$ 26 s 5/2+# $\Delta = -61792$ (10) $\beta = 100\%$	$^{162}_{63}\text{Eu}_{99}$ 10.6 s $\Delta = -58690$ (60) $\beta = 100\%$	$^{163}_{63}\text{Eu}_{100}$ 7.7 s 5/2+# $\Delta = -56640$ (70) $\beta = 100\%$	$^{164}_{63}\text{Eu}_{101}$ 4.2 s $\Delta = -53330\#$ (210#) $\beta = 100\%$



Contributions to FOA's funded projects

Objective

Significantly improve Nuclear Data in the Fission Product region - cross-cutting overlap with the main ND stakeholders **DOE-SC/NP** (Nuclear Structure & Astrophysics) & **DOE-NNSA/NA-22** (applications)

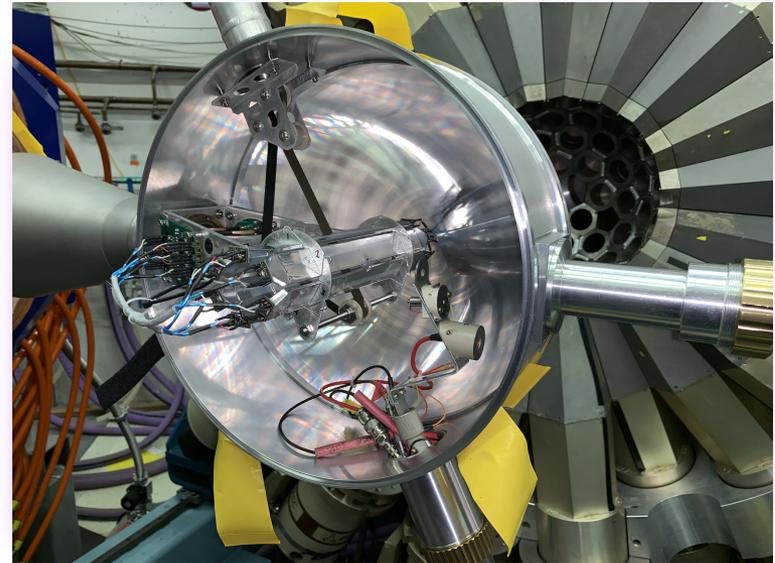
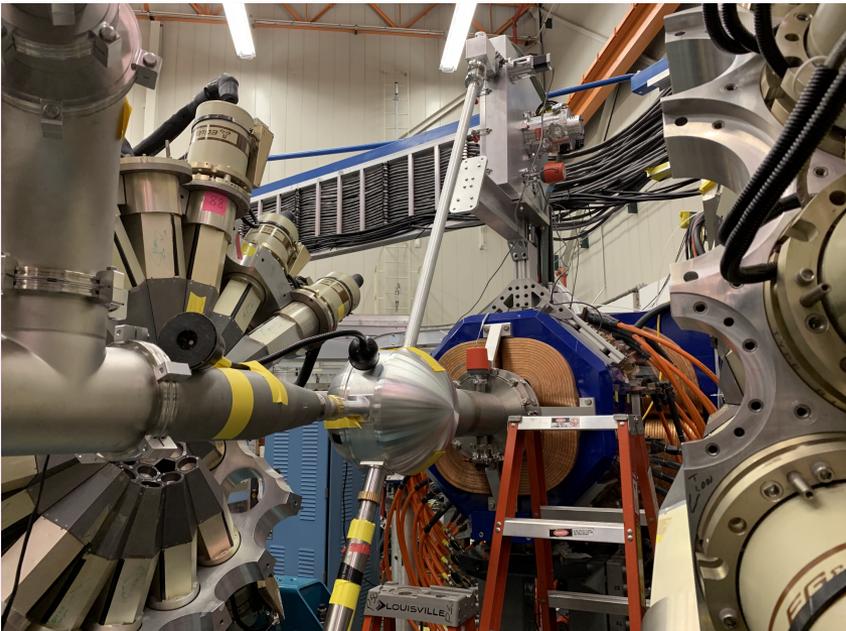
- ❑ Improving the Nuclear Data on Fission Product Decays at CARIBU (PI: G. Savard)
 - ✓ 5 years project
 - ✓ collaboration with LLNL - \$1M from **DOE/SC/NP** to **ANL** and \$1M from **NNSA/NA-22** to **LLNL**

- ❑ Novel Approach for Improving Antineutrino Spectra Predictions for Nonproliferation Applications (PI: F.G. Kondev)
 - ✓ 3 years project - \$375K from **DOE/SC/NP** and \$405K from **NNSA/NA-22**
 - ✓ collaborations with **LSU**, **WUSL** & **USNA** & others via **IAEA-NDS** coordination

GammaSphere decay station

Advantages

- discrete & calorimetry γ -ray spectroscopy techniques within a single device
- high granularity & resolving power ($\Delta E_{\gamma}=2$ keV, P/T~60% and $\epsilon_{\gamma}\sim 85\%$) - ability to resolve weak γ -ray cascades (10^{-5} - 10^{-6} %)
- complete decay schemes - angular correlations for transition multipolarities & J π assignments - end game in nuclear spectroscopy



- HEART - HExagonal ARray for Triggering
 - ✓ 6 EJ-204 plastic scint. & 12 SiPM
 - ✓ $\epsilon_{\beta}\sim 75\%$ from β - γ singles & coin.
- powerful γ - γ - β -t coincidence device

$^{146}\text{g,mLa}$ - masses & half-lives

Y. Khazov et al., NDS 136 (2016) 163

(6 ⁻)	141.4 (26)
(2 ⁻)	9.8 (4) s
	0.0



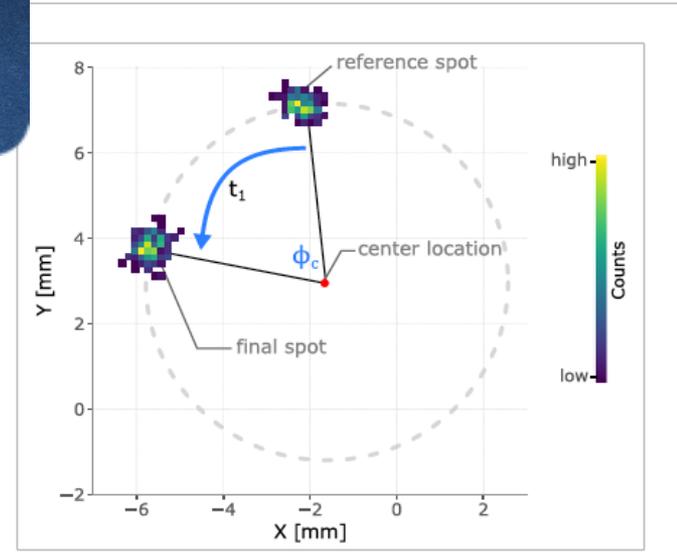
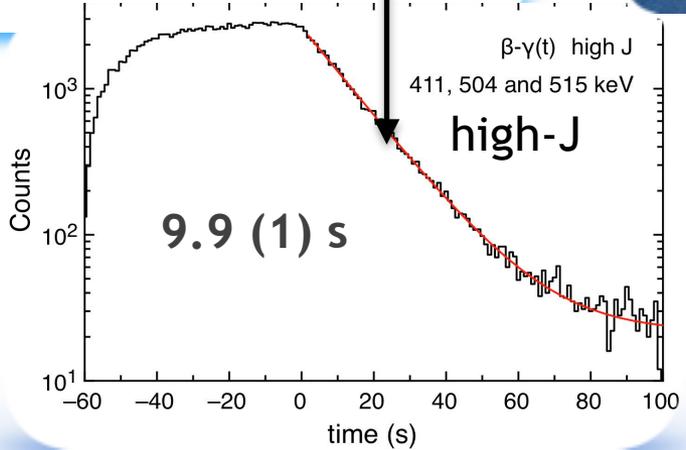
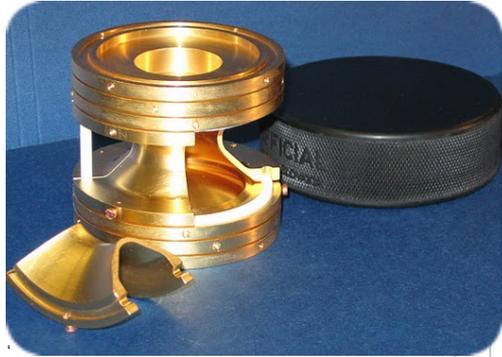
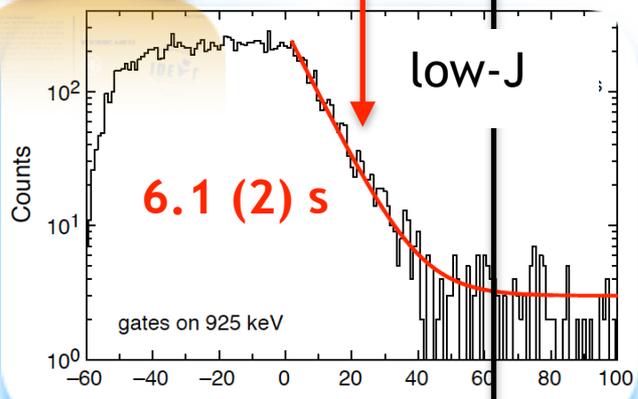
Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Improving the measurement sensitivity of the Canadian Penning Trap mass spectrometer through PI-ICR

R. Orford^{a,b,*}, J.A. Clark^{b,c}, G. Savard^{b,d}, A. Aprahamian^e, F. Buchinger^a, M.T. Burkey^{d,b}, D.A. Gorelov^{c,b}, J.W. Klimes^b, G.E. Morgan^{c,b}, A. Nystrom^{e,b}, W.S. Porter^e, D. Ray^{c,b}, K.S. Sharma^c



$^{146g,m}\text{La}$ - Gammasphere decay station

Y. Khazov et al., NDS 136 (2016) 163

(6^-) $0.0+X$

$(1^-, 2^-)$ **141.4**

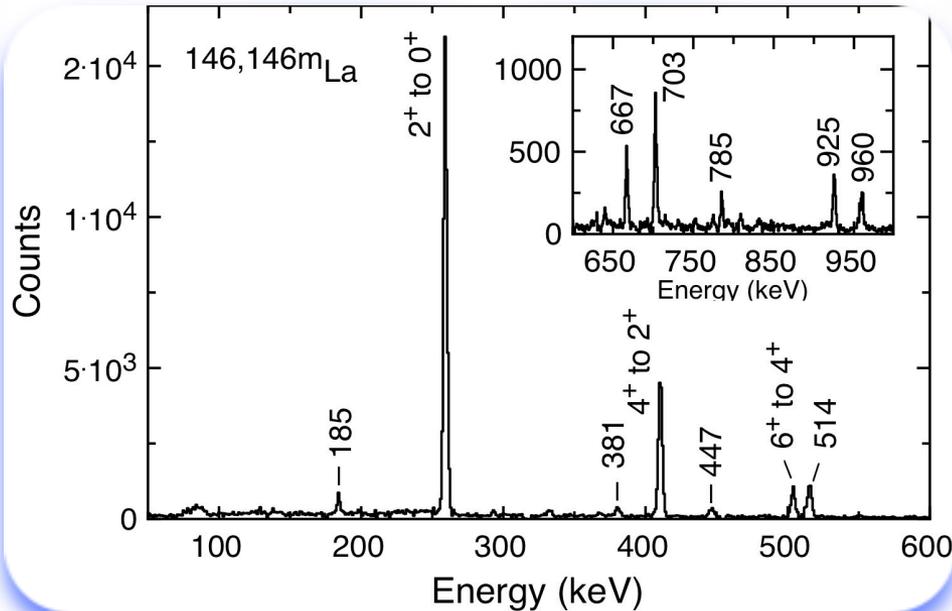
$\pi 5/2^+[413]$ $\nu 1/2^-[530]$

(2^-) 0.0

(5^-) 0.0

$\pi 5/2^+[413]$ $\nu 5/2^-[523]$

Nilsson assignment



- resolved gs and isomer decays
- new levels and transitions
- new $J\pi$ and configurations
- new nuclear structure interpretation - deformed shell model

Future (FY19 and beyond) Plans

- ❑ Continue contributing to XUNDL & ENSDF - top priority - closer connections with ATLAS & FRIB user communities
- ❑ Continue AME & NuBase collaboration activities
 - maintain the currency (5-6 yrs cycle) and quality
- ❑ Continue topical collaborations with IAEA-NDS, other USNDP groups & wide nuclear physics community - B(E3) evaluation update (with T. Kibedi, ANU)
- ❑ Continue research activities with emphasis on nuclear structure physics and astrophysics, and their intersection with the applied nuclear physics
 - **ATLAS & CARIBU (nuCARIBU)**: nuclear structure, masses & astrophysics, with emphasis on properties of neutron-rich nuclei in the deformed, light rare-earth region ($A \sim 160$)
 - **N=126 factory**: the heavy region south of ^{208}Pb - nicely overlaps with the ND evaluation responsibilities
 - **nuCARIBU**: contributions to FOA's and other interagency ND projects
 - **NSCL (FRIB), RIKEN & IMP (HIAF)** - nuclear structure, masses & astrophysics

Publications & Invited talks - FY18

- Publications in refereed journals: 17
- Invited talks: 11

Personnel & Effort - FY19 & FY20

- base ND program
 - ✓ 1 head (staff) - 0.85 FTE SC/NP/ND
 - ✓ 0.15 FTE (FOA funding from NNSA/NA-22 & SC/NP)
- will expire in FY20
- ND FOAs
 - ✓ 2 heads (post-docs) - one funded through FY20, the other through FY22